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Locomotive Boiler Examination,
Defects and Repairs.

(Part 2.)

BY

W. J. BENNETT, Member of Council, Brighton.

With an abstract of the discussion upon the Paper.

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(OF TRANSACTIONS).

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PAPER No. 20.

Locomotive Boiler Examination, Defects and Repairs.

(Part 2).

BY

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In dealing with the second part of the paper on "Boiler Examination, Defects and Repairs," it is proposed to confine attention, as closely as possible, to boiler repairs. Railway engineers, and steam users in general, would be very much startled if they were aware of the strains that are sometimes put upon their boilers, by reason of the unskilful way in which one part is made to fit the other; that is, the parts are not properly prepared to receive each other. This results, in many instances, in strains being put upon the material through the parts having to be forced into position by drifting or other similar means, the material only being saved from fractures during the process by the elasticity of the different metals used; and it is these strains which might, with very little extra pressure, cause the boiler to explode with disastrous results. Engineers are sometimes apt to consider that a boilermaker who does not care to take unnecessary risks, and who prefers to have things put quite safe when boilers come in for repairs, is "an alarmist"; but it is certainly much better to be careful, and such a man is more valuable than one who takes chances which should not be taken and who does not use common-sense in arriving at what may mean to him, and to the travelling public, a most momentous decision. These so-called "accidents" have occurred in past years, and, when the matter has been made a subject of inquiry, it has been found that the boiler was made by one of the best makers, fitted with

all the latter-day improvements, was known to have had a sufficiency of water at the time of the explosion, and that the safety valves were properly adjusted; so the conclusion has been arrived at that the cause of the accident might be some mysterious action of the water within the boiler; but there is no doubt, in some of such instances, that the boilermaker responsible for the building of the particular boiler could have thrown some light upon the matter had he dared to do so.

The same things happen in the repairing of boilers as in the manufacture, the repair man requiring just as much skilled training to be properly fitted for the work he has to do as the man engaged on new boiler construction. The boiler inspector should also be a highly skilled man, not only in theory, but also by actual everyday experience as a working boilermaker, and his expert advice should be adopted when repairs to boilers become necessary.

There is no doubt that railway companies have achieved splendid results by careful periodical examinations and by seeing that necessary repairs are done before weakened parts become dangerous, but this goes to prove that eternal vigilance is the price of success. Yet the men who are responsible for, and who have achieved these results, do not, in some instances, get either the consideration or the salary which should go far to recompense them for the very heavy responsibilities they have to incur.

Boiler repairs can be placed in two quite distinct classes, one class being the running repairs (more generally spoken of as shed work), and the other depot repairs, when engines are sent into the shops for general overhaul, which, in most instances, takes place after from eighteen months to two years' service, sometimes even longer.

Running shed repairs generally take the form of taking out wasted and broken stays, re-caulking of seams, changing of wasted flange and firehole rivets, tubes to be re-expanded, owing to leakage, or change, if any should get badly worn or burst, the careful looking after of the washing out of the boilers, changing of the fusible safety plugs periodically, and examination of the boilers generally as often as possible, boilers generally being given an examination on wash-out or shed days and small repairs done; but when larger repairs than can be done in the short time at command are required, the engine is put out of service, and is then left in the shed boilermaker's hands for these larger repairs to be completed, or sent to the shops if too heavy for the shed boilermaker to handle.

As regards running shed repairs, probably one of the

most common is the changing of broken stays; and, as it is necessary to get this work done with the least possible delay, it is a general practice to put them in—what is termed—steamtight, which means that no outside lagging is taken off the boiler, in fact, nothing is dismantled, the boilermaker told off for the work simply going through the firehole into the firebox and doing all that is necessary. *Fig. 1* shows tools that will be required during the operation.

The method of changing a stay and putting in another one "steamtight" is as follows:—

No. 1. A straight punch is used after the stay head has been cut off on the inside of the firebox and the centre hole has been drilled in stay, to punch down the stay clear of the hole on the copper firebox side of the boiler.

No. 2, a bent chisel, is then passed through the stay hole, and is used to nick the stay as far round as possible against the casing plate. The straight punch (No. 1) then comes into use again for breaking the stay down into the water space and for levelling up the portion of copper stay left in the casing plate, so that it presents a reasonably level surface for the drill to be used upon.

No. 3, a long centre punch, is used for centering the piece of stay now left in the casing plate for drilling out.

No. 4, a long drill, is also required for drilling a hole through it.

No. 5. The next is termed a fishback tool, and comes into use to pick up the shuck of copper now left in the casing plate.

No. 6, a narrow cross-cut, is also required for cutting the shuck to pieces for removal out of the hole, and

No. 7, a sharp-pointed round nose, is used for removing any pieces of the shuck that have not been moved by the fishback.

A piece of wire is then used, if necessary, for drawing the pieces of shuck out of the hole.

When these operations are completed, the hole is ready for re-tapping; but as the manufacture of steamtight stays has been explained in Part I. of this paper, it is not proposed to weary the reader by an unnecessary repetition of it.

The stays, when manufactured, are introduced into the boiler by means of a gauge-depth studbox, the distance from plate to plate outside having already been measured by a rule made specially for this purpose, and the proper length of the stay required found from this measurement plus the amount inside the studbox, which also is the length required to knock down on the firebox plate to form the head.

The work is then completed by the removal of the studbox, and the stay being hammered over and snapped to form the head. *Fig. 2* shows the difference between the riveter and the steamtight stay in manufacture (exaggerated).

After going into the matter of the tubers' work done at the different running sheds, the author is of opinion that this is what is responsible for a great amount of our existing tube-plate troubles. Engines come in from day to day, their drivers reporting in the book "tubes leaking," and the tuber is sent to touch them up. Probably the engine is booked for going out again within a very short space of time, the result being that the tuber goes into the hot firebox and begins driving up the ferrules while the tubes and tube-plate are still hot, and so distorts the plate much more than would have been the case if more time had been available, so that he could have taken out the ferrules and re-expanded the tubes properly. The driving home of the ferrules may certainly stop the tubes from leaking badly for a trip or two, but then it has to be repeated, whereas the expander, if properly used, would have put the tube back to the plate for the whole thickness of the tube-plate, the taper on the ferrule, in being driven further up, only expanding the tube on the outside edge of the tube-plate, and having the tendency to bulge the tube-plate towards the smokebox, and also to crack the plate between the tubeholes. Unfortunately, this trouble cannot be entirely done away with, want of time being chiefly the cause; but much has been done in saving tube-plates from cracking by introducing the practice of putting reduced-sized tube holes in the outside rows all round in the copper tube-plate. (*Fig. 3* shows tube-plate so dealt with), $\frac{1}{4}$ -in. reduction in the size of the holes for these outside rows being generally considered ample to give the tube-plate the extra bracing up required: that is to say, for a copper tube-plate which has previously been drilled for taking $1\frac{5}{8}$ -in. diameter tubes, the outside rows, when the tube-plate is removed and a new one is put in, are drilled for tubes reduced to $1\frac{3}{8}$ -in. diameter.

In taking into consideration the expanding of tubes, it will be found that opinions differ very much as to the tools to be used, some preferring one special make of expander, and others, drifting only.

The drifting of tubes to make them tight is most detrimental to the life of the tube-plate, whilst expanding with a first-class expander most certainly prolongs the life. Some people prefer the old "Dudgeon" pattern expander, but, personally, the author prefers either the "Wickstead," which is self-feeding (the rollers in revolving drawing the

mandril in, and so feeding the pressure required on the rollers), or the "Enak," which has a screw-adjustment for placing the rollers at any reasonable distance that they may require to be moved either forward or backward from the end of the tube. At the same time, for a good ordinary every-day tool the old "Dudgeon" pattern is hard to beat.

With the introduction of the superheater, and the consequent necessity for having very large tubes put in the boiler to take the superheater tubes, some considerable amount of trouble has been experienced in keeping the large boiler tubes tight. The reasons for this have at different times been the subject of much thought and discussion, but the author is of the opinion that, if the difference in the longitudinal expansion of the firebox forward and the tubes from the steel tube-plate end of the boiler towards their hottest point at the firebox tube-plate, be taken into consideration against the longitudinal expansion of the barrel and casing, it will be clearly shown that no trouble with these large smoke-tubes is experienced at the steel tube-plate end, but that it occurs to the tubes at the firebox end only, when the expansion of the tube rearwards from the steel tube-plate is met by the expansion forward of the firebox, this movement resulting in the breaking of the joint made by the tube expanders at this point. The longer the fireboxes and tubes, the greater this trouble, and it is also aggravated when engines are not so carefully handled as they might be. Shrinkage of these smoke-tubes in diameter takes place at the firebox end, and no further application of uniform heat can re-establish them to their proper size, with this result, that the tubes have to be re-expanded out again to make a joint at the copper tube-plate. But this trouble appears to be found more especially on round crown boilers, where the tube-holes go elliptical in the two top corners, which necessitates the removal of these tubes periodically to have the tube-holes rounded up again; and, as the tubes are costly, it is most advantageous, if these tubes can be got out of the boiler without being damaged, for them to be softened and used again in the same boiler after the holes have been attended to. (*Fig. 4* shows a set of tools designed for this purpose.) They are as follows:—

A bar of iron $1\frac{3}{8}$ -in. in diameter screwed at both ends, and long enough to reach from the firebox tube-plate to the outside of the smokebox, is provided. This is passed down the tube till it protrudes at the firebox tube-plate end. A piece of steel, about 5-in. diameter by $3\frac{1}{2}$ -in. long, is then turned down to the inside diameter of the tube for about $1\frac{1}{2}$ -in. up, beyond this point is turned to the outside diameter

of the tube for another $1\frac{1}{2}$ -in., and again, beyond this, is turned to a larger diameter than the hole in the tube-plate, to save this part of the tool being drawn into the boiler barrel. This is put on the bolt at firebox end and the nut put on. A somewhat similar washer is provided for the smokebox end of tube to slip into the tube end, so as to keep the long bolt central in the tube; and to keep this washer from slipping out of position, a clip is now slipped over the bolt and screwed tight up against the washer. The girder bar is then passed over the end of the bolt projecting beyond the smokebox front and fastened up in position on the front by means of two hooked bolts, so as to save the necessity for moving it when another tube has to be drawn out of the tube-plate in the same row, as the long bolt can easily be drawn through the girder bar and put into its new position in the next tube, provided that the bar has been placed lineable with the centres of the rows of tubes to be operated upon. A long spanner is also provided for screwing up the nut at the girder bar end, the box nut tool being put over the nut at firebox end, and, whilst a sharp blow is being given on the end of this tool with a tuber's hammer, the men using the spanner at the smokebox end tighten up the nut, and so the tube is drawn out of its seat and is then ready to be taken out of the boiler.

But this arrangement will only answer where the tubes are not screwed into the copper tube-plate. If the tubes should have been screwed in, a grip will have to be fastened on to the smokebox end of the tube, and the tube unscrewed out of the plate; or, if the tube should have been distorted badly, it would have to be ripped up at the firebox end, set in, and so withdrawn. (*Fig. 5* shows the tools in position for removing tubes as mentioned.)

If, when the tubes are taken out, the holes are found to be so badly elliptical in shape as to require rounding up, another set of tools is required for the purpose. In fact, some of the holes may be so bad that, when they have been cleaned out to round, it may be necessary to bush the tube holes or else put in a new tube-plate, which latter being so expensive, if the tube-plate can be saved by inserting either a steel or a copper bush, it is wise to do so; and with this in view, it is proposed to explain the use of a set of tools designed for this purpose, as follows:—(*Fig. 6*) a reamer and tap with a pilot attached to each, the pilot being used in conjunction with a pilot plate, which helps to hold the reamer and tap in position when they are being used, this pilot plate or guide being held in position by turned collared spindles, which are put into the small tube-holes, the plate

being specially marked off from the old tube-plate which is receiving attention. (*Fig. 7* shows this pilot plate and the method of attaching it to the copper tube-plate.) A large ratchet spanner is then used for doing the necessary reamering and tapping of the hole, owing to the work being done by hand labour, the ashpan being taken down to allow the lever of the spanner to be used in conjunction with a rope; so that one man will be attending to the reamering and tapping inside the firebox whilst two men are outside pulling on the rope attached to the lever and working under the control of the man in the firebox. (*Fig. 8* shows this set of tools rigged up ready for use.) Whilst the reamering and tapping are being done, the man responsible for the work should take particular care to notice how far the tap is screwed into the plate to get a good full thread, and should note on paper the length that the tap still stands out of the tube-plate for each hole tapped, as this will be an excellent guide for the turner who is manufacturing the bushes to work to, as regards the different sizes of the bushes required; because, as soon as the tapping is completed, the actual tap used can be handed to him for him to work from as regards size. As too much taper is not required on these bushes, one in sixteen being found quite sufficient, it is well to see that the taper on both the tap used and the bush to be put in agrees, or a bad job will be the result. To screw the bushes into the tube-plate will also require a special tool, and to allow of this tool doing its work without interfering with the utility of the bush, it is advisable to let the bush protrude through the plate into the water side of the barrel at least $\frac{1}{2}$ -in. This $\frac{1}{2}$ -in. will then allow of the bushes being slotted out in four places to take a key tool to pull them in with, the slots in the bush allowing the key tool to fall into its proper position; and a turned washer reduced to fit the tube-hole being already in the bush, and a nut having been put on and screwed up to keep everything in place, the tool and bush are then ready to be put into the tapped hole; and when screwed in as far as is required, the man doing this work will release the nut and take it off the screwed end of the tool and withdraw the washer, and then, passing his hand through the next tube hole, will remove the key tool. He can then fasten another bush on to it, and so be ready for bushing the next hole, so continuing till he comes to the last hole requiring to be bushed, when it will be necessary for someone to go inside the boiler to bring out the key tool. (*Fig. 9* shows bush and key tool with washer and nut.) After the bushes are in position in the tube-plate, it is

advisable to hammer them over on the firebox side with a light stay hammer all round the outside edges, and it is advantageous to caulk them with a spoon tool on the inside of the barrel before putting in the tubes. Where tubes are not screwed in, it has been found advisable to send them to the lathe and have them grooved, about four grooves $1/64$ -in. deep and $1/16$ -in. in width generally being turned on the tube ends at firebox end. These will give the tubes a better grip of the tube-plate than they would have, if this was not done; but, when the tube-plate is bushed, it pays to groove the tube-hole in the bush, as this saves the carting of the tubes to and from the lathe. A racking tool is sometimes used, and this acts somewhat in the same way as a tube expander, it being set in the tube so that the centre of the roller, which has a bead formed on it, will depress the tube on the inside of the tube-plate in the barrel, and so form a knuckle or ridge to stiffen the tube at that point, after which operation the tube is expanded into the plate with either a three, five, or seven-rollered expander, according to the number of rollers preferred by those responsible for this work. It is well known that the most skilled work, as regards tubing, has always to be done at the firebox end, and the author is of opinion that, even for the large smoke-tubes, an enlarged "Enak" expander with seven rollers adjusted to roll the tube out just inside the tube-plate would give satisfactory results in stopping the breakage of the joint at the firebox end caused by the differences of expansion, as explained previously.

Fig. 10 shows various methods of collar-bolting and studding.

About the changing of rivets in firebox seams, it is not proposed to say much, as this matter was dealt with in the first part of this paper.

Sometimes when boilers come in for repairs it is found that the roof of the firebox, tube-plate, back-plate, and upper sides are in splendid condition, but that cracks leading from the stay-holes on the sides down in the fire are found, and that the stay-holes may have become so enlarged by having been several times re-stayed that it is impossible to do anything else but "half-side" or put a patch on the bad place to endeavour to see the remainder of the box out. Personally, the author is decidedly against these patches, but, like other people, has at times to tolerate them; but he certainly thinks, in these cases, where such patches are either put on the outside of the old plate and studded on, or when the hole is cut out large enough rectangularly to allow of the new plate being dropped down

in the water space, that many of the troubles that have been experienced with them have been caused by being so conservative as to demand the standard lap in each case outside the rivet hole, which, roughly speaking, is the diameter of the size of rivet used. These laps really are abnormal for the class of work the patch has to do, seeing that they are subjected to so fierce a heat, being practically laid in the fire, and, owing to the double thickness of the material, not getting sufficient water to keep them from being badly eaten away by the impinging of the flame and heat, it being found that 90 per cent. of all the trouble in this patching of fireboxes down in the fire is really due to excessive laps. If the amount of lap was reduced to, say, $1\frac{1}{16}$ -in. from centre of holes to outside of lap, it would be found that, taking it for granted that $\frac{7}{8}$ -in. stud bolts were used, the water would have a chance to get nearer to the caulked edge of these patches, and so do away with so much of the trouble and talk of firebox patches being sprung or leaking. At the same time, it is well understood that this class of patching in a firebox is the most difficult repair that can be done to get from the boiler the highest mileage possible, without failures. At the same time, in many instances, the foreman does not take such an interest in this class of work as he might do, and, consequently, the workman is allowed to go his own way, and, generally, he follows the way of keeping to a standard lap, not taking into consideration the different aspects of the jobs he may be engaged on, and simply taking it for granted that what is right for one job must of necessity be quite all right for the next.

When it is found that patches will not eradicate the bad portions in the fire, it is sometimes found advisable to crop the firebox sides, and, if this is done, the crop should be made high up, so as to prevent the flame striking the lap formed by the junction of the new and old plate at the end of the brick arch and to help the joint of the two plates to remain good, so that the life of the new plate put in will be prolonged more than would be the case if cut lower down in the fire.

When firebox half sides are put in, it is generally the practice to take out the boiler foundation ring and turn the boiler over on its back so as to rivet them in, in preference to studding, and, when this is done, it requires a first-class holder-up on this work to ensure that the rivets are well held up. The class of riveting required for this work is called Wedge Bar Work, the rivets being passed down the water space and put into the hole with a pair of spring tongs,

a small cup tool with a $\frac{3}{8}$ -in. iron rod screwed into it to be used as a handle being then put down on to the head of the rivet, a long steel wedge being then introduced between the cup tool end and the boiler casing side and driven tightly into position. Another man then holds on the outside of the casing plate with a holding-up hammer at the point where the wedge bar is driven against it, and the riveter then knocks the rivet down and finishes it off with caulking tools. This is, of course, an expensive job, and some of the rivets in very awkward positions have been known to cost as much as two shillings each before they could be put in and finished, the rivets having, at times, to be bent to get them into the holes, owing to the narrowness of the water spaces at some points.

When the copper plate at the fire-hole is badly eaten away, and it is found that the other portion of the plate is good, a fire-hole patch only is then put on, the bad or eaten away portion being removed and a new plate formed and put down inside the water space, it being found to be much the better practice to allow the new plate to be slipped down inside the old one, leaving the old one to form the lap, as this allows of the lap being put further away from the action of the fire; but to do this means taking out a few more stays, to enable the plate to be passed into position. To have these patches riveted on by wedge bar work, which is certainly preferable to studding, necessitates all the fire-hole ring rivets being removed and the ring being made loose; also, more stays being taken out in the top portion of the back-plate, so that the ring can be moved up out of the way to allow of the holder-up manipulating his cup and wedge bar tools; but the job certainly pays for this little extra expense.

Sometimes, however, it is found that, not only is the plate at the fire-hole edges licked away, but the side flanges as well. It is then best to put in, what is termed, a half back-plate, this generally being cut as high as the top portion of the fire-hole ring. The new plate thus fitted is lapped over the top of the old plate at the cross seam, but, when, as is sometimes the case, the top roof flange of the back-plate is also eaten away, it is best to remove the old plate altogether and put in a new one.

Copper tube-plates require more attention and careful handling than back-plates. The portion where the tube-holes are drilled oftentimes becomes bulged, either forwards or backwards, during the time the boiler is out on service. It is necessary, when this is found to be the case, to remove all tubes and re-level the plates; and if this is not carefully

done, cracked bridges will be the result, and, probably, to such an extent that a new tube-plate will be required. It is advisable, therefore, when a plate requires bulges to be set back, to do the work by steady pulling, in preference to heavy hammering, and for an angle or tee bar of the length required to be placed across the plate at the bulged portion with screw bolts with washers placed under each end of the bar to keep it from touching the plate and to allow for any spring there may be on the bar; so that, when the bolts are being screwed up to force the bulged part back, the plate does not come in contact with the bar before the desired amount of setting back is done.

But if, as often is the case, the bridges of the tube-holes are cracked, and more work is desired to be got out of the tube-plate before scrapping it, bushing of the tube-holes where the cracks are is resorted to. Many people believe that this bushing stiffens up a tube-plate, but this it does not do. Bushing is no good as regards strengthening, but is done with a view to prolonging the life of a tube-plate for a time, probably another twelve to eighteen months. More life can be got out of the tube-plate if the work is properly done, but, with this class of work, there is a certain percentage of failures, due, in some instances, to the want of care or knowledge on the part of the boilermaker who is doing the bushing. It has been found a good practice where cracks are following one after another down the tube-plate bridges, to introduce a $\frac{3}{8}$ -in. or $\frac{1}{2}$ -in. thick copper plate (sufficiently wide to take about one row of tube-holes each side of the cracks found) inside the boiler barrel and attach it to the tube-plate over the cracked portion, leaving the cracks as near central from the edge of the patch as possible, and bushing the patch on to the cracked portion with copper sleeve bushes, through which reduced tubes can be passed afterwards. The tube will then help to support the tube-plate at this point; and this is far preferable to having the cracked tube-holes bushed only, because, if the bushes are simply screwed into the holes, the crack is still between, with nothing to stop it from leaking. But, at the same time, where only a few cracks are found between the tube-holes, and probably all the tubes are not required to come out, to make a quick, and, for the time being, a moderately efficient job, the locking of bushes, as it is called, is oftentimes done, one tube-hole being reamed out large enough to take out rather more than half the cracked bridge, and a solid bush screwed into position into this tapped hole before the next hole is operated upon; and when the second hole is reamed out, it cleans a small portion out of the first bush put in. When

the hole is tapped, the two bushes are practically locked together by their threads being in conjunction with one another, but sometimes, where this has not been done, it has been found necessary to drill a hole between the bushes after they have been screwed into position, tap the hole, and screw in a piece of $\frac{5}{8}$ -in. or $\frac{3}{4}$ -in. diameter copper, and so lock the bushes and eradicate the crack by this method.

When the lower flanges of the tube-plate and the rivets are found to have become wasted, the bad rivets are taken out, and, if there is a moderate amount of lap left on the holes in the flanges, countersunk collar studs are put in; but sometimes the laps are found to be badly eaten away, and, if the firebox should be an old one which has nearly reached the limit of its existence, sometimes large-headed copper collar bolts are screwed on, and these heads are so lapped on one another as to practically cover the small portion of the old lap remaining on the flange, so protecting it from the fire, in order that a few more months may be got out of the box, it being much better if all parts of the box can be practically made to last out one another.

If the tubes are coming out and wasted rivets are found requiring to come out, it is advisable to put rivets back where possible, because the more the holes are tapped out for studs, the weaker the laps become; and, as the fire does plenty of damage to these by licking them away, it is wise not to have them weakened by anything which can be avoided.

Crowns of fireboxes also require much careful consideration. Possibly the driver may, through some cause or another, have allowed his boiler to get short of water, and this may have caused the copper to bulge downwards between the roof bolt pitches. Also, the roof bolts, if overheated through this, have become loosened, and the plate may be found to be fractured, requiring all roof bolts to be taken out of the boiler, the bulges set back, the plate made level again, and, if the plate should have been found to be damaged, a patch on the roof would be required. The author has heard before now of dry patches being put over such cracks, but such an idea is not good practice. If a patch has to be put on, cut out as much of the old plate, besides eradicating the crack, as is possible, to allow of the water being able to get at the new patch when put on. If this is not done, the patch will be nothing but a source of trouble and annoyance, if not actual danger, during the time the engine remains in service.

For bad pitting or grooving, oftentimes found in the bottom part of the boiler barrel—especially in the modern

steel boilers, dry patches are put on, 5/16-in. or 3/8-in. steel plate generally being used, the bad places being well cleaned, the pittings filled up with a mixture of red lead and fine cast-iron borings and then painted with oxide or red lead paint before the cover patch is fastened on for good, to stop, as far as possible, the water from attacking the pitted portions again.

When the firebox of a boiler has got into such a bad condition as to require a new copper tube-plate, two new half firebox sides, and a new half or whole back-plate, I consider that, when every cost is reckoned, it is really more economical to take out the firebox complete and fit the casing with a new one. I grant that, looking at the two jobs, it appears to be the much more costly one to cut out and put in a new firebox; but, when the fact that it costs much more for men to work in confined and awkward places is considered, the amount of time it takes to cut away and release the old rivets, plates, etc., as against the ease and quickness with which an old firebox can be released and taken out of the casing, also the heavy costs for fitting in the new plates, as against the moderately cheap costs of making and fitting in the new firebox, a different complexion is certainly put on the matter. To release a firebox for taking out of casing, the foundation and fire-hole rivets are first removed, and the copper stay heads drilled for breaking down on the casing side only. If the roof is direct stayed, these stays will also have to be drilled at crown of casing and a punch used to break them asunder through the drilled holes in the end of the stays, but, if it should be a solid or girder barred boiler, it is generally found to be more expeditious to simply cut out the rivets in the crown support angles and draw the bars and crown support angles all out together with the firebox. But before this is done the foundation ring is generally removed, and, to do this part of the work as quickly as possible, it is found advisable to lay the boiler down on its side, and cut out a piece of copper about 4-in. square at the foundation part of the copper box near each of the corners of the firebox wrapper plate, so that the men can use their steel wedges to shift the ring through the small opening that is then made between the foundation ring and the copper plate by this small piece of plate being cut away. After the ring has been released sufficiently to get the crane to work, it is lifted out. The boiler is then turned on its back, and the men break down the stays clear on the casing side; and, when everything has been released, the crane again comes into use, to lift the old firebox out, after which the shucks or

remaining portions of the copper stays left in the casing plate stayholes are removed with a round nose, and the casing is then ready for examination and for whoever is in charge to say what repairs it is necessary to do to the plates forming the outer casing of the boiler.

Generally, it is found that the stay holes on the casing are more or less enlarged through the stays having been removed several times, the re-tapping of the holes accounting for the increase in the sizes of the stays afterwards put in, so that, to bring the stay-holes back to their original size, it is found necessary to drill them out to a size large enough to allow of a bush being put in.

But this is only done up to a certain number of bushes, because, if too many bushes are required on the sides of the casing, it is cheaper to crop the casing and put on new plates than bush the old ones, these bushes costing on the average about 1/- each for material and labour when complete in casing.

Grooving at the edge of the foundation ring inside the water space is also generally found to have taken place, sometimes so slightly that a thin protection liner can be studded on and the studs riveted over, the ring having been chamfered off first to receive the liner and the liner planed with a long bevel edge to fit well down into the edge of the ring so chamfered off. But oftentimes the throat and back-plate at this point are found to be so eaten away by the action of the water-space rods and dirt accumulation that it is necessary to be more drastic, with the result that a crop has to be made to cut the old plate away. When the portion of old plate requiring to be renewed has been removed, the edge of the existing portion has to be heated and set back so as to receive the drawn corners of the new plate and to give it the desired set off to fit against the foundation ring when being fitted. After the new patch plate is fitted, it is taken down, marked off and drilled, and the portion of each plate overlapping properly cleaned, so that, when bolted up for good, they fit closely together. No plates must be allowed to be bolted together without this being done, or a leaking job will be the result, proper care taken at the right time showing the efficiency of the workman responsible.

By the time the casing and barrel have received their overhaul and have been again put in a perfectly sound condition, the firebox should be marked off, drilled, sheared, planed, put together, riveted, and caulked, so that it is available for marking off in the casing as soon as required. Taking it for granted that such has been done, the founda-

tion ring must now be fitted on to the new firebox; and, when this is done, the firebox should be put in the casing and set into its proper position, care being taken that the right amount of water and steam space has been allowed for at the top of the firebox, also that it is placed central in the casing, to allow of the water space being equalised on each side from the centre line of boiler. If this is found to be correct, the box is marked off for the stay holes and necessary rivet holes, and is then taken out and sent to the drilling machine for the drilling to be done.

If the boiler should have a girder-barred roof, these bars should by now have been overhauled, and, if the ends of the bars had lengthened whilst in service in the old box taken out, they should be heated and jumped up at the ends to allow of a proper fit being made on the new box radius corners, it being most particular that the ends of the bars should be properly fitted, so as to distribute equally the weight put on them when the boiler is again in service. When the box has been drilled, the foundation ring is again taken off to clean it free of drillings or dirt, and the box is handed over to the roof bar man to fit his bars and put his bolts in, providing the box is fitted with the hollow class of roof bar. But, should it be a boiler fitted with solid bars, the bars are fitted on and the roof bolt holes drilled, the bars being left off till after the box is in position, riveted and stayed, after which the solid bars are put on, the roof bolts screwed up, and shackles and pins adjusted to suit the height of the box, so as to give the amount of rigidity required for the down pressure the crown will have to sustain.

With a direct-stayed boiler being re-fireboxed, the same operations are gone through, except that, after the firebox is put in, the boiler is turned down on its side, and the stay holes in the outer casing are tapped in conjunction with the firebox crown, the stays then run in, cut off to length—on the outside if a round-crown boiler—and nuts put on inside the firebox. The outside heads of the stays are then riveted over and snapped, after which the nuts on the inside of the firebox are taken off, and the roof bolts caulked with a pneumatic rotating hammer and a round sleeve caulking tool. The sleeve caulking tool has a hole drilled down it far enough to well clear the end of the stay and $1/32$ -in. larger in diameter, so that the tool does not damage the thread on the stay whilst it is rotating.

When the caulking is completed, the nuts are put on again and screwed up tightly with a short box spanner, and the lead plug or fusible safety plug is put in the crown.

The boiler is then ready for the internal pipes to be fitted, to be tubed and tested, about eight weeks being the average time required to cut out an old firebox, replace with a new one, and test the boiler, ready for again going into the engine frame. One thing more must be mentioned: great care should be taken to see that no obstruction be allowed to remain in the water spaces, and so cause dirt accumulation. Tools are sometimes left in boilers, and in other cases articles have fallen into the water spaces by accident, but all reasonable efforts should be made to remove them before the boiler is put into service.

In conclusion, it is most difficult to give an idea of boiler repairs that could be considered as standard practice, the general conditions on one railway being so vastly different to those on others, these differences being very complicated, and due, in many instances, to different systems, also different designs of boilers, and troubles due to the peculiar properties of the different feed waters; and, again, there is so much diversity of opinion between boilermakers and repairers themselves, some disapproving of what others emphatically state is good practice, each being perfectly justified according to his own peculiar experiences. Consequently, the author can only hope that some of his opinions may prove to be of interest.

DISCUSSION.

Mr. Williams, sen., opened the discussion as follows:—

In the first place I feel sure I am correct in saying that we would all like to congratulate Mr. Bennett upon an excellent paper. The subject is a most difficult one and the clearness with which Mr. Bennett has brought the many points forward does him great credit. As Mr. Bennett said in his closing remarks, all systems do not use the same design of boiler, consequently we repair them differently, and our ideas of repairing differ very much. I wish now to refer particularly to the levelling of copper tube-plates. Mr. Bennett has shown us that it is possible for this to be done, but my experience leads me never to allow a copper tube-plate to be levelled in repair, because the chances are you break it across the bridges, or if you do not do that you start a fracture that will develop later on. But what we have done in relation to this matter is to weaken the steel tube-plate, thereby giving to the steel tubes a little more liberty to expand in this direction.

Mr. Williams then explained this idea, with the aid of sketches made on the blackboard, showing a flanged boiler ring and the front row of rivets joining it to the barrel, reduced in number by one half, and also referred to the fact that palm stays between the tube-plate and the barrel prevented the breathing of the tube-plate when the boiler barrel was going backwards or forwards by reason of expansion or contraction, and that they had discontinued using these for years past. He also agreed with Mr. Bennett that the longer the box the more aggravated was the trouble as regards leaking tubes. As a result of the weakening or lessening of the rigidity of the steel tube-plate and doing away with the palm stays, they never have a buckled copper tube-plate.

Another point—we also bush our copper tube-plates when they are severely cracked, but if a plate were cracked to such an extent that more than five bushes were required in any one direct line, we would remove the plate; because with the high pressures we have to contend with now, I consider it is not good practice to run too great a risk. Then again, Mr. Bennett suggests that it might be possible in some cases to put liners inside the copper tube-plate. That I have never done, because you cannot get the water

up against your tubes, and the chances are you get trouble very quickly.

Mr. Williams then proceeded to explain, with the aid of the blackboard, the method of bushing used by him. He said that the width of the tube-plate bridge in most cases was not more than $\frac{3}{4}$ in., although he believed that on the South Western Railway they were $\frac{7}{8}$ in., and that if the tube-hole was enlarged to a 2 in. tapping hole, there would be only $\frac{3}{8}$ in. of metal left. The bush used by him was shown upon the blackboard. It extended over the copper tube-plate a $\frac{1}{4}$ in. on either side and was put in just tightly enough so that it could be turned by using a small mandril. The hole in plate was parallel, which he preferred, and the internal hole was $1\frac{1}{4}$ in. diameter.

After being put in, the bush is hammered out over both sides, but if we are doing the job in the running department and cannot get inside the boiler because the tubes have not been taken out, we have a long piece of steel with a guide at one end, and bead the bush over on the inside as well as possible. When done, and the tubes all put in, we are able to bead these over and thereby cover up the crack. In all cases they have been found to last out the tube-plate.

Mr. Bennett spoke of the use of solid bushes; I have not practised this because it takes away the whole of the copper which should form the bridge. As regards bushing large smoke tube-holes for our superheater boilers, I have not had much experience in that matter, because we have about $1\frac{3}{4}$ in. of metal between our large tube-holes, that is to say, they are 6 in. centres and $4\frac{1}{4}$ in. diameter, which gives you a $1\frac{3}{8}$ in. bridge, and consequently we do not find bushing necessary. If a tube has to be taken out, we have found it better practice to cut it for that purpose, rather than draw it out, for the simple reason that the tubes, after they have been running, are so hardened by the tube expander and the many changes in temperature they undergo, that it is not wise to try to re-expand and bead over the same portion. When we wish to use a smoke tube again we cut off about 6 in. from the end and weld on a new piece. We have experimented with lengthening tubes, it is quite a simple matter, but if you do so, you still have that hard substance to deal with that will not bead over again; so, from a practical point of view, we have considered it best to employ welding. Grooving of steel casing plates, we have found it a very good practice to insert a thin piece of copper between the ring and the casing plate when the grooving is not very deep; but if the groove is

found to be rather more than half way through, we remove the part that is grooved and put a patch on as Mr. Bennett has remarked. However, in a good many cases we are fitting this piece of thin copper between the casing plate and the foundation ring when building the boiler, and it almost completely stops the grooving trouble. The grooving, of course, takes place from several causes. One is the unequal expansion between the thick foundation ring and the casing plate itself, which results in the strained fibres of the material breaking down under the least provocation. Another is the striking of deposit against the plate by the rapid circulation at that point.

Mr. W. A. Lelean—Gentlemen, the difficulty seems to be to know where to begin and where to stop, as there are so many points of interest in this paper of Mr. Bennett's. I am sure we all agree that this is a most valuable paper, and feel deeply indebted to Mr. Bennett for the way in which he has put it before us. First, with reference to the question of ferrules, Mr. Bennett seems to say that the driving up of ferrules only tightens the tube at the outer edge. We had some difficulty with ferrules at one time, which were reported to be too soft to stand up when being driven, although we had the usual taper on the ferrules of 1 in 20, so that they were about 1-16 in. bigger at the large end than at the small. On putting them into a parallel hole the size of the small end of the ferrule, which was made in a steel block, it was found, as Mr. Bennett states, these ferrules were only bearing at the mouth of the hole, and on driving the ferrules yielded at each blow and drove quite flush without being really tight throughout their length. We then made the expander and the ferrules carefully to the same taper, and when we put these ferrules in we found that a comparatively light blow made the tubes quite tight. We came to the conclusion, though, that the ferrules should be harder, and we now specify that ferrules must not close more than half their diameter without cracking. If ferrules are made thus and the expander is made to expand the tubes to exactly the same taper as the ferrules, I think that would lessen the trouble Mr. Bennett refers to.

In connection with the tube arrangement at the side of the firebox, Mr. Bennett has drawn attention to a very effective way of meeting the difficulty from cracked side bridges, and the only objection to it seems to be the stocking of two sizes of tubes. Where straight lines of tubes occur

at the sides of the box, we have tried putting each alternate tube out of line, avoiding in this way the straight line of bridges through which fracture can take place. In this connection we have had reports where Locomotive Superintendents have tried a reduction in the number of tubes in the boilers, and from the statements received we have come distinctly to the conclusion that the "paper" heating surface is oftentimes obtained at the expense of the copper tube-plate, and we now keep our bridges 1 in. wide as against the $\frac{3}{4}$ in. bridges referred to by Mr. Williams. If engineers would be satisfied with a smaller number of tubes, I do not think they would materially lose in the actual evaporation obtained from their boiler, and they certainly would gain very much in the life of the firebox tube-plate. Then, as to the expander, the Enak certainly seems one of the best forms on the market. The advantage claimed for it is that by pressing the body of the expander up against the tube-plate "wobbling" is prevented and the expanded hole is kept truly round throughout the thickness of the tube-plate. Mr. Bennett referred to the turning of grooves in the tubes, and this we have found beneficial in stopping the blowing of these tubes. The great point about these grooves seems to be not to make them too deep, say 1-64 in. deep by 3-32 in. wide is sufficient. If you make them too deep you do not seem to be able to get the copper of the tube-plate to press into and fill the grooves. With reference to the pitting of the barrels, there seems to be a consensus of opinion that the "Apexior" boiler preservative, or any similar preservative in which the basis is plumbago, is really quite useful in preventing the formation of scale, and further, in loosening scale already formed; but we are told that if you put in a $\frac{1}{4}$ lb. of free plumbago (graphite or blacklead) with your feed water, you will find that this will settle on the tubes and plates and will actually penetrate the scale and loosen it from the boiler, acting thus as well as these patent paints. Those dealing with boilers daily can easily experiment and see if any benefit is derived from this. With reference to the corrosion of the outsides of boilers, I have brought here a pamphlet which is most instructive to anyone interested in boiler work, showing photographs of examples of corrosion on various boiler-plates. This is a report which the Cape Asbestos Co. had prepared by an expert, because it was feared by them that their asbestos mattresses were being practically pushed out of use, because of the corrosion which was said to take place on the boiler-plates, due to these mattresses. I think

it is only fair to the Cape Asbestos Company, and all other asbestos mattress makers, to say that it is not true. It is not the asbestos which causes the corrosion, but it is the leakage that takes place. When leakage takes place it does not matter whether it is asbestos or whatever clothing it may be, as anything that retains moisture naturally increases the corrosion. To condemn asbestos mattresses on this account seems hardly fair. There is no doubt, judging from these photographs, taken from a great number of engines and boilers, that the chief corrosion on the outside casing of the firebox and the boiler generally is usually found adjacent to the wash-out holes. There has been a device introduced to prevent the water getting into and saturating the clothing; this consists of a collar studded to the boiler around each wash-out hole and made watertight thereto by a lead ring or other jointing material; this collar is carried out through the lagging plate and formed with a flange to which the lagging plate can be attached, and with a lip on the lower side to drain off any water that overflows when washing out. Apart from the advantage of saving the saturation of the clothing, these collars enable the engine-man to see at once when a wash-out joint is blowing and to report same. This device seems well worth trying.

In connection with the removal of the firebox, Mr. Bennett showed us illustrations of tools consisting largely of a series of chisels, and most ingenious arrangements many of them were, but it has occurred to me whether it would not be possible to devise a saw, to be worked by the pneumatic plant, for cutting these stays, similar to that used in some works for cutting off the stays to length on the outside of the firebox after the stays are screwed into place. Failing that, some modification of the eccentric stay cutting shear seems possible. If made with a slot through the side so that it could be pushed over the stay and the eccentric then made to rotate by a revolving worm and segment, it might be found possible to shear the stays instead of cutting them off with a chisel.

I was very much struck by Mr. Bennett's mention of the necessity for scaling the plates of the boiler. I am quite satisfied that this is a very strong point. In new boilers some firms now even go to the extent of scaling their boiler plates between the joints by means of very hard steel shot. This shot is very fine, about the size of a good sized pin's head, and it is intensely hard, so hard that it cannot be cut with a file; this is made to impinge on the scale of the plate by means of a jet of air, very much in the same way as

sand is used when sand blasting is done. This has to be done in a steel lined chamber, so that the shot does not fly all over the place, and the floor is formed hopper-like, so that the shot can be collected. The shot removes the scale perfectly and can be used over and over again without deterioration.

Then Mr. Bennett said, in putting in crown stays, after having them riveted on the outside, that it is his practice to remove the inside nuts and caulk the stays round with a hollow caulker. As an alternative I have seen nuts used with a V section projection, about 1-16in. deep, turned on the underside. The diameter of the projection is about $\frac{1}{8}$ in. larger than the diameter over the threads of the stay, and the inclined sides enclose an angle of 60° .

When such a nut is screwed down on the copper firebox this V tends to wedge a piece of copper tight into the thread, making the joint tight without the need of caulking. This is found to be quite efficient in keeping stays tight.

Another thing I saw used in a German shop, which I suggest to members present to try when riveting down their side stays. They turned the boiler on to a baulk of timber and used an ordinary jack with a very quick right and left hand thread, like a screw coupling, to press against the under side of the holder-up, with the result that they had an absolutely solid surface against which to rivet. It certainly produced very good work and prevented the straining of the thread in the copper, such as takes place when the head is riveted over without being efficiently supported by an holder-up at the opposite end.

I was much struck with that portion of Mr. Bennett's last paper in which he showed the ill effects of a scribe mark. That is a point I would like to put to those present, who are in every day contact with firebox repairs. Is it necessary to caulk the outside of copper fireboxes at all? It is a continual fight with the workmen and one does not want to limit them in their endeavour to make a creditable looking job, but the danger is that a man will go with a very narrow edge chisel to cut off the fin raised by the pneumatic caulker and will therewith nick the flanged plate. It seems to me that the only safe way to avoid this nicking of tube and door plates is to prohibit caulking of the wrapper plate on the outside of the box. If the box is well plated and the wrapper plate well laid down before each rivet is put in, I doubt if more harm would result from leaving the edge uncaulked than now so often results from

the accidental or careless nicking of the flanged plates when cutting off the fin raised by the pneumatic caulkers.

Mr. Flocks—I agree entirely with all Mr. Bennett has said with the exception of the bushing of tube-holes. Mr. Williams has referred to this matter, and I may say I have had experience of bushing these tube-holes with the bush indicated by Mr. Williams for at least 11 years. When we have a few holes cracked we bush them, and I have never yet known this method to fail. We certainly would not put on a liner inside. We think we have got the correct and a perfect method. It has given splendid results. I examined a boiler this morning, one which had been out running and had come in for repair, and these bushes are as good to-day as when we put them in. Mind, you must be careful, you want the very best man to do it. The bushes are parallel—one must lap the other in the firebox and also in the waterway and cover the crack up entirely. We have boilers running to-day which have been out at least two years and the bushes are quite good. I do not think Mr. Williams explained about the size of tube-hole in the new bush; it would be $1\frac{3}{8}$ in. diam.

I was noticing one of the lantern slides showing a saddle-plate with grooving. I think it is a common failure on locomotive boilers, this grooving round the foundation. For some considerable time now we have been using a very thin sheet of copper. I remember a boiler that came in for repairs that had been running long enough to use out the first firebox and we found considerable grooving, so we put on a very thin sheet of copper and covered the grooving. We sent the boiler out again, and when it came back again with the second box used up, that grooving had gone no further during the whole of the life of the second firebox. The thickness of the sheet of copper would be about 1-16 in. It gives splendid results. One other point in Mr. Bennett's paper. He refers to the raising of a roll in the tubes just in front of the copper tube-plate for large smoke-tubes. When expanding your tubes, I understand, the rollers of your expander were so placed that the back edge of the roller was just flush with the front edge of the copper tube-plate so that the tube was expanded with a slight shoulder against the front of the tube-plate. We have adopted this method and with splendid results. Prior to using that we could not keep these smoke-tubes tight, but this has been the remedy. If you have any trouble of this kind we can

honestly recommend that this is a very good remedy. It has proved most beneficial in our case, and now we have very little of which to complain. At first the tubes were not grooved at all, then we tried a slight grooving on the tube, which we pressed into the copper, but that was not effective. We have found that the expander is our best remedy—we could put a decent shoulder inside the plate, inside the waterway, as Mr. Bennett explained.

(Mr. Flocks illustrated his remark by a sketch on the board.)

As Mr. Bennett clearly pointed out in his paper, the shoulder prevents the breaking of the joint between the tube and the tube-plate. It is quite understood that with the expansion that is taking place the bead is not doing you any good—it is clear from the plate; but this depression prevents the joint being broken and causes the plate to come with it.

Mr. Williams, sen.—Mr. Bennett mentions something about grooving the bush rather than the tube. In the case of large smoke-tubes I should like to know if he has had any experience in that matter, for it struck me that it would not meet the case, so far as I can understand the necessity for grooving, inasmuch as you would not be able to depress the steel tube into the steel bush.

Mr. Nethercot—Mr. Flocks, and also Mr. Williams, spoke of bushing, and they did not agree with putting the plate on the back, inside the waterspace of the boiler. I understood from them that they bush only for, say, about three, four, or five holes. I understood Mr. Williams to say that he would not bush more than five. If you can save that tube-plate for a matter of 18 months or two years by putting in 15 bushes, surely it pays you; and we have instances, not one, or two, or three. I have had instances of the same class of work for 14 or 15 years, and those tube-plates have lasted well with as many as 30 or 40 bushes—that is going rather heavy. By having the plate behind you really do not make the tube-plate much thicker than some engineers have their tube-plates at the first onset. The average tube-plate runs about $\frac{7}{8}$ in., but a good many engineers have their tube-plates $1\frac{1}{4}$ in. and $1\frac{3}{4}$ in. thick. The "La France" worked with $1\frac{1}{4}$ in. plate, consequently, if you put $\frac{3}{8}$ in. plate behind a $\frac{7}{8}$ in. tube-plate, you are not making it much thicker than a thick tube-plate would be at first. Then again, Mr. Lelean mentioned not caulking roof bolts. The class of nut I believe Mr. Lelean means

certainly may make the bolts tight for a time; but should one of these leak you are spoiling the stay by taking the nut off. These nuts really do not make the direct stay tight. You should not depend upon that nut; it does not make the stay steam tight. It never was intended to. (Hear, hear.) If you begin to take that nut off in the shed you spoil the stay. The result is you have either to run that stay down a shade smaller and put on a smaller nut, or else take the stay out wherever it happens to be. Mr. Lelean also mentioned not caulking fireboxes. Personally, while not believing, to a certain extent, in caulking inside everywhere, as you cannot always get at it, I would like to know how you can make it tight other than by caulking.

Mr. Lelean—By caulking the inside edge of tube and back-plate against the wrapper-plate, on the inside of the firebox.

Mr. Nethercot—From your remarks again with reference to use of sharp edge so as to clean off the rag, the same thing applies. That would be really outside the water space, a much worse position than inside the firebox, where no one would be able to see it. My opinion is that the caulking, if done properly, should be done both inside and outside the boiler; because it is certain that if you prevent the steam getting from the inside to the line of rivets you have a much better chance of making it tight than if you only caulk outside. (Hear, hear.)

Then Mr. Lelean mentioned grooving only taking place at the mudhole. My experience does not point that way. I find grooving round any joint where you get two plates close together. Those are the places which are more liable to pitting, such as in the lantern slide, which Mr. Bennett showed, of a side-plate. That groove was certainly not at the mudhole, so that any leaking of the mudholes was not the cause. As Mr. Williams explained, there are two or three different reasons—the expansion of the plate against the foundation ring, the grease that may be inside the boiler, and various other things, and, as Mr. Williams said, I remember when I was up there and saw him, some two or three years ago, noticing those thin pieces of copper he was having put in. We have found very good results, but instead of using copper, we are putting on inside, as Mr. Bennett remarked, steel liners, usually from $\frac{1}{4}$ -in. to $\frac{5}{16}$ -in. thick, these being chamfered and fitted down tight against the foundation ring. We, also, have had cases where we have taken out old fireboxes and found these steel liners in nearly as good a condition as when put in.

Mr. Flocks—Just one word in reference to that liner. We did, on one or two occasions, put in a steel liner, but it did not last. We have never found copper a failure. We have never detected any further grooving after putting the copper in, but we did find that the steel had gone right through.

Mr. Nethercot—I might also say, in regard to grooving, that it makes a great difference, the class of water used. I have seen new steel boilers at the end of eighteen months' service absolutely grooved the whole length of the barrel, round the throat-plate, and at the foundation, so much so that liners had to be put on the full length of the boiler, and new casing sides and new casing back had to be supplied, and a patch on the throat-plate, besides two patches higher up, at the junction of the throat. But on the steel boilers we have been making for the last seven years we have not found, up to the present, any appreciable grooving, such as is found on some railways, especially in the barrel. I think that, to a very large extent, that is prevented by having a lining of cement put inside the barrel previous to any tubes being put in when the boiler is new. It forms a scale for the plate itself, and really prevents the action of the water on the plate. Absolutely cleaning the boiler down to the plate itself is not, in my opinion, such good practice as having a very thin egg-shell-like covering on the plates for working purposes.

Mr. Williams, jun.—Mr. Bennett said that, in putting a new firebox in an old boiler, in order to mark it off for drilling, he would put the ring on the firebox, fix it in the boiler, and mark it off with a long centrepunch through the holes in the casing. I am of opinion that it is better practice to mark it off from a template. I should imagine there is a saving of money by employing this method, and better results are obtainable. Of course, the templates used are made when the boilers are first built, and kept for all boxes of the same type. It has been found to work satisfactorily on the G.E. Railway.

Mr. Lelean—With reference to the question raised by the last speaker, it might be interesting to members to know the practice followed in one of the largest contract shops; their practice (at least, up to a year or two ago) was to put each firebox into its casing and mark the stay-holes in place. After the fireboxes had been marked off in place, they were taken out and the holes corrected so as to keep them in straight lines. I have seen boilers not marked off in this

way in which stays have come considerably out of their proper angle when put in. It is very difficult to always avoid twist in the fireboxes, and it certainly seems the safer method to mark off the stay-holes on the copper box when it is in place. In connection with the question of expansion, it is not always possible to get hold of actual figures first hand, and it may be interesting to members to learn the result of an experiment we have just carried out to determine how much the crown of the copper firebox goes up in relation to the outside shell when steam is being raised. The boiler tested had a Belpaire-shaped firebox, and the crown was stayed with direct stays throughout, except the front four rows, which were passed through tee brackets slung from tee bars on the inside of the shell, these stays being passed through a clearing hole in the tee brackets having a nut at the top end which rests on the tee brackets, so that the stays are free to rise through the brackets as the crown lifts when getting up steam. A hole was drilled in the outer wrapper plate, immediately over the centre rivet in the joint of the copper wrapper-plate to the tube-plate. This hole was fitted with a stuffing-box through which a $\frac{3}{8}$ -in. stiff steel rod was kept pressed in contact with the top of the centre rivets in the inner firebox joint by a spring. On the fire being lighted, the copper expanded, and the crown rose, steadily pushing the rod out of the stuffing-box. This movement, however, only reached a maximum of just $\frac{1}{16}$ -in., which occurred immediately before the pressure began to come on the boiler. From that point the crown dropped, until at 50lbs. pressure it was the same distance from the outside shell as when the boiler started from the cold. Thereafter, with each 25lbs. rise of pressure there was a perceptible movement of about .004 inch, till at 180lbs. the crown of the inner box was about $\frac{1}{64}$ -in. further from the outer shell than at starting. This experiment seems to prove that immediately the pressure begins the crown drops till the roof stays take the strain. It is interesting, therefore, to consider what must happen when the tube-plate has been stretched by the successive expandings of the tubes till the flange of the tube-plate has gone up $\frac{3}{16}$ -in. or more. Further, when we come to consider that there is probably over a quarter of an inch difference of expansion between the boiler shell and the copper firebox and its tubes, we can quite understand something of the difficulties Mr. Bennett has referred to from broken bridges in the tube-plate.

Mr. Williams—Mr. Bennett was good enough to give us a slide showing a crack right round the crown of a

boiler, caused, of course, by the continual buckling of the copper, on the corner. We went into that matter some few years ago, and I found the deeper the box, the more this was aggravated. The firebox in a round-top boiler is prevented from adjusting itself to the expansion of the sides of the box. It goes up and down in a body, and will not accommodate itself to any expansion, with the result that the little radius between the first row of roof bolts and the first line of side stays has to take up all the expansion and contraction of the sides, and also of the crown. The crown expands and the sides lift, with the result that the radius which forms the corner, no matter how large or how small (we have in some of our boilers a 6-in. radius there, giving just as much trouble), has to take it up. The only way to remedy this is to have a flat-topped boiler, so that, when the boiler goes up, the whole thing goes up together, and the crown accommodates itself to the depression caused by the pressure of the steam upon the crown of the firebox.

The Chairman then called on Mr. Bennett to reply to the various points raised in the discussion.

Mr. Bennett—Gentlemen, I must thank you all for the kind attention you have given to my paper, also for the discussing of the various points which appealed to you, and I shall have to ask you, if I should miss any questions which you would like me to answer, to kindly give them to me again.

In the first place, Mr. Williams, sen., spoke about the levelling of copper tube-plates. He did not care to level copper tube-plates on repair boilers at all. Well, it certainly is best if it can be dispensed with, but in some instances the tube-plates get badly bulged towards the fire by the driving up of tubes in the sheds, so that it is imperative that something should be done, and in these instances, if the tubes should happen to be removed, it is certainly best to put the tube-plate back to level by screw-bolts and bar, in preference to hammering it back.

Mr. Williams stated, I think, that he has a way of somewhat weakening the steel tube-plate, and also dispensing with the barrel palm stays at the copper tube-plate, which, he states, has the tendency to allow the tube-plate to breathe more freely—also, that he has reduced the radius of the throat-plate where it is flanged through to form the barrel flange, and so has been able to pitch his copper stays nearer to the edge of the flange. In doing this, does it not seem that you have made for more rigidity? If you begin to

reduce radii, you are doing away with flexibility; consequently, if you have got any working taking place at that point, you are giving the plate the tendency to gall at the smallest radii of the flange. I do not know whether you have had that happen up to now, since you made the alteration. Personally, I think it would not be good practice.

Mr. Williams—Mr. Bennett refers to the saddle-plate. We have not had any of our stays giving the slightest trouble.

Mr. Bennett—You say you have never put any liners on copper tube-plates, as mentioned by me—the putting of a thin strip liner $\frac{3}{8}$ -in. thick down inside the water space over the cracked portion, bushing it on, and putting reduced tubes through, but that you have a system of bushing which, I gather, has been entirely successful. Do you screw these bushes in, or simply clean the hole out to round, put the bush in, and bead it over on both sides?

Mr. Williams replied that they were screwed in.

Mr. Bennett—So that, after all, it is only a hollow bush, and you lap them one over the other; but you do not eradicate the crack—you do not attempt to?

Mr. Williams—No.

Mr. Bennett—You are simply relying on the amount of caulking, and the lapping of one bush on the other? You say you have never had any failures?

Mr. Williams—No.

Mr. Flocks—I mentioned the fact particularly for your benefit, because we have had really a good experience. We leave $\frac{1}{4}$ -in. of copper and completely cover it up by lapping one bush on the other. The result has been splendid.

Mr. Bennett—What is the result of leaving the crack there?

Mr. Flocks—We have covered up the crack on both sides of the plate.

Mr. Bennett—In the working of the plate in service, the crack is opening all the time, and consequently the bushes are not helping to hold it together at all.

Mr. Woolford—How does it hold together by having two bushes that interlock? There is no metal at all.

Mr. Bennett—In the expansion forward of the firebox the threads are locking one another, so that they cannot give; whereas, in the other case, you have not got that—they can work on the crack, and it does not appear to me to be so serviceable. This is simply my opinion.

Then, again, Mr. Williams, you say you do not bush superheater tube holes, and if you took superheater tubes out as I suggested, they would be too short. That depends, of course, upon the peculiarities that you may adopt as regards your boilers. In my case, I leave a matter of $1\frac{1}{4}$ -in. standing out beyond the steel tube-plate, so that, in the event of the smoke-tube being removed from the boiler, I could afford to saw $\frac{1}{2}$ -in. off, to get back to good material, and still have more than enough as regards length for my boiler. Of course, in some cases, it is the practice to cut them off and bead them at the steel tube-plate end as well as at the firebox end. But I do not do that.

Mr. Williams—We have not room to leave more than $\frac{5}{8}$ -in. extending beyond the steel tube-plate, because the bend of the superheater elements comes too close to the tube-plate.

Mr. Bennett—With Schmidt's superheater, we have room to leave them out 2-in., if required. That is the peculiarity. I could not quite understand why you should say they would not be long enough. I took it for granted that you were probably beading them at the steel tube-plate end.

Mr. Williams—Have you had experience with bushing the tube holes in relation to the smoke-tubes?

Mr. Bennett—Yes; we have put twenty-one steel bushes in a copper tube-plate, and this was done because the holes were gone badly elliptical. This was in a round-crown boiler, and in a round-crown boiler with direct stays, the tube holes all go elliptical more or less, the long portion of the hole running upwards towards the centre of the tube-plate from each side. This, of course, is occasioned by the working of the crown of the firebox and expanding of tube holes towards the point of least resistance. But this bushing was only done as a matter of experiment—it was, and is, simply in the experimental stage.

The lesson we learnt from it was this, that it is advantageous up to about eight months; after that, the bushes themselves began to give trouble; but for the period mentioned we saved the tube-plate. It means to say that,

provided you have a job come in, and by some means or another you may have neglected to order another copper tube-plate of that sort, and it would take you perhaps two or three months to get one from the makers if you ordered it as soon as your engine came in for repairs; if you wanted to return this engine into traffic as soon as possible, then I say it would be advantageous to bush up the tube-holes, put reduced end tubes in, and let the engine go again; but not to bush as a standard practice.

You also spoke about introducing a piece of copper at the foundation ring to prevent grooving. Mr. Nethercot was kind enough to answer that for me in some respects, because he told you what we have done at Brighton. We introduce a piece of $\frac{1}{4}$ -in. steel, and we have very good results from that. I want to say, however, that after a liner of this sort has been on five or six years, we have found that it has become slightly grooved; if ordinary boiler steel will groove during the time it is in service, through the use of the water-space rod, the liner plate put on will also get worn in the same way. I should have thought that copper introduced there would have set up some kind of galvanic action, and done more harm than good. But still, your experience is a proof of its being a good thing. We do not come here with the idea of forcing our ideas upon other people, but with the hopes of learning something from those who discuss the various papers given. I might have said this, though, that, if you found trouble with your steel liners, I am rather surprised that you did not try a common iron one, because you are not putting this liner in as a strengthener, unless you are planing away your foundation ring and taking your liner right through—when, of course, it would be a strengthener, and would require to be of boiler-plate quality; but for use, simply as a protection plate, common iron is not so liable to pit as steel, and I should have thought it preferable to copper at that point.

Mr. Lelean was speaking about driving up ferrules, tightening them up on the edge. I said that, in driving up ferrules, it had the tendency simply to expand the hole on the outside edge. I am still of that opinion.

If you have $1/16$ -in. of taper in $1\frac{1}{2}$ -in. long, you have ample drive on a ferrule. Even then, we find that the use of the tuber's hammer and the action of driving up the ferrules does harm to the tube-plate; it knocks the tube-plate forward, bulging it towards the steel tube-plate, and so, incidentally bulging the steel tube-plate outwards as well.

Driving ferrules up is a very bad practice, and should be dispensed with as much as possible.

As regards the keeping of two sizes of tubes, owing to reducing of the outside rows of holes of the copper tube-plate, that is not really necessary. Order the tubes to the largest size of hole, and reduce the ends of the tubes under a Ryder Hammer or with swaging tools, as they are needed, to the required diameter for about $2\frac{1}{2}$ -in. up from the end. It costs very little, and saves the keeping of two stocks. As regards caulking inside the firebox, that depends upon what is described as caulking. Some identify caulking with the use of the narrow seam tool. All boilers are caulked, but we term it fullering—that is, when the stuff is simply fullered down and no seam tools used at all. Personally, I do not believe in the caulking tool at all other than the fuller, nor do I believe in the use of the splitting tool to do any splitting or anything of that sort to distort the laps of the plates, but I do believe in fullering the copper firebox inside and out, and if this is done properly no fin should be allowed to flow in front of the caulking tool, and not being in evidence, would dispense with the necessity of having to be cut off with the sharp chisel, which, as Mr. Lelean explained, if not carefully done, would nick the plates, and so form a start for a fracture. As I have already mentioned, we want to keep our laps as good as possible, and to do this we must take care not to do anything to distort them in any way, or to do any extra chipping, but to endeavour to save as much material as we can.

Mr. Lelean mentioned the use of plumbago or graphite for scale treatment. I might tell you my experience with graphite as a boiler cleaner. Twelve months ago last September I started using Dixon's No. 1 coarse flake graphite on a stationary boiler, one that gave us most trouble from dirt accumulation. I had put in it 3lbs. of this graphite (it costs $\frac{1}{8}$ to $\frac{1}{9}$ per lb.). The boiler previously had been washed out once a month, but I let her run for seven weeks before having her opened out, and then we were somewhat delighted with what we found. All the dirt that had accumulated during that seven weeks ran away in the form of sand and water. Some of the old scale had also been lifted off the boiler. Then, with a view to reducing costs, I started putting in 1lb. per month, and this has kept the scale from forming, and has also loosened the old scale, so that we gradually began to see the boiler plates. Every now and again pieces of the scale would flake off. The graphite seems to penetrate right into the scale and lift it off right down to the plate.

Mr. Lelean—That is exactly what I was told.

Mr. Bennett—I was rather anxious to see how the graphite was affecting the face of the plate and the rivets, and the tubes (iron), having been in about five and a half years, and getting bad, I had a good excuse for re-tubing the boiler. We took the tubes out about eight weeks ago, also the scale which had lifted. It did not want breaking off; it was there ready for us to clean out in great pieces, some of it being as much as a foot square and about $\frac{5}{8}$ -in. in thickness. In fact, for many years the boiler has not been so clean as it is to-day. And I can truly state that we have found very good results from the use of graphite as a boiler cleaner.

Talking about shearing off stays, that is quite an old idea. We used to shear them off many years ago. In fact, the tools are still in the shop, the same as Mr. Lelean has mentioned for cutting them off to length on the outside. But it is better by far to cut the stay off with a proper chisel made to a very fine, sharp edge; that does very little damage.

Mr. Lelean—I was referring to taking fireboxes out, when you are breaking down the stays inside.

Mr. Bennett—In that case, you cannot do better than use an ordinary water-space rod set. You cannot get at them with a machine; at least, I have never seen a machine (except an American "Rivet-buster" with tools made to suit) with which you could get at the stays in the water spaces to nick them in two.

Mr. Williams—We made an attempt, as Mr. Lelean suggests, but we could not get enough power to drive the machine, and it was more bother than it was worth. We found it was better to cut them off in the usual way.

Mr. Bennett—We can break the stays down at something like sixpence per dozen. I am sure we could not saw them off for that money. As regards the hollow caulking tool for roof stays, I might tell you that last winter I went to Swindon and saw them using this sleeve tool for caulking steel stays on the boiler side. They were $\frac{5}{8}$ -in. stays, as a matter of fact, and I said to one of the foremen there: "I wonder you don't use that on the roof stays." He replied: "It is no good for that." I thought it was. I brought the idea back home, and have used this class of tool ever since; and I am well satisfied that it caulks my bolts

efficiently, and at the same time effects a saving of 33 per cent. on the old prices paid.

With regard to the class of roof nut described by Mr. Lelean, I do not think that any foreman boilermaker would be guilty of adopting it if he had anything to do with deciding the point. I find it best to keep to the flat nut. We simply use this nut as a retainer for the roof, in case by any means the thread should wear off in the copper. We do not use the nut at all with a view to keeping the stay tight.

Mr. Lelean—I do not propose that nut as a method of rectifying a bad-fitting stay. I think, emphatically, the stay should be tight. I was only suggesting it as an alternative to caulking round the stays.

Mr. Bennett—If you use a nut of the same design as you have described, you would be distorting the thread on the stay by forcing up the nut, so that you would be doing harm instead of good. If the hole in the firebox crown-plate is tapped true to pitch and size, and the bolt is also made true, then the very action of tightening up the nut would have a distorting effect on the thread in the copper plate. You see, it is almost like using a jack to force the copper off the thread on the bolt. We have had experience of them. Some years ago some boilers were bought out, and when they were delivered we had them re-tested, and some of the roof bolts leaked rather badly, and when we took the nuts off, much to my surprise, I found they had V collars turned on at the face of the nuts, the same as you are suggesting. All these nuts were taken off as the boilers were delivered, the roof bolts properly caulked, and flat-faced nuts put on, and after this we had no further trouble. As for riveting copper stays by putting something firmly on the floor to hammer on, that is wrong. You want a certain amount of rebound. If you want to have something solid to hammer on, you might as well put the boiler on a block and do it.

I should not like to be responsible for boilers that were built like that. No; give me flexibility. The very fact of a stay not having a certain amount of bump on it—I do not mean that a man should deliberately bump a stay—but the action of the holding-up hammer rebounding off the stay and back again, causes a certain amount of play, so that you do not get such a solid drive on the stay, which would so surely crank or bend the stay in the water space between the two plates if you were having the stay held on, in the way suggested. As regards the scribe mark, the use of

the scriber is to be deplored. It is unnecessary, but sometimes men do not think. If they had thought there was the possibility of a simple scriber mark setting up fracture like that shown by the lantern slide, they would have been the first to desist. This actual piece of copper, with the scriber mark and the resulting fracture, was marked off in my own days at Brighton, and the piece was taken out five years afterwards. I remember passing the job myself. We have been into the matter of the bushing of the tube holes, as mentioned by Mr. Flocks. If he has not known a failure, he has been much luckier than I. I can say this, that my biggest successes have been really gained through my previous failures. If you never get any failures, I am afraid you will never gain any really valuable successes. As a matter of fact, as Mr. Nethercot explained, we have saved some of our tube-plates for as much as four years by our system of bushing, and we have gone so far as to put in as many as thirty bushes. It is not a good practice, but at the same time it is a saving, and we have to study finances everywhere, of course; and if we can save a tube-plate for four years, that is a very good saving, for, as a rule, the life of a tube-plate under the best conditions is not more than five or six years, and you are lucky if you get that.

Speaking about the "Enak" expander, and the use of the racking tool for beading or ridging the tube against the inside of the copper tube-plate; by using the "Enak" expander, the collar of the expander can be unscrewed far enough back to allow the ends of the rollers to be close against the inside of the tube-plate, so that the tube can be expanded out on the inside to form a ridge the whole length of the rollers, which are about 2-in. long; and then you can move the collar forward again and expand the tube back to the tube-plate. Of course, if you start on the inside first there is a tendency for the tube to be slightly reduced in size at the end where the rollers are not touching, whilst the pressure is being put on to form the ridge inside, so that you are forced to come back and expand the tube on to the tube hole before the job is completed.

As regards beading, I might say that, when Mr. Walters was present to hear the first portion of this paper, in April last, he explained to us that they did not bead their tubes right down to the plate, but only part beaded them, or, rather, opened the ends projecting into the firebox by using a cone tool, and that he considered he had good results from this practice. I thought there was something in it, and accepted the lesson. I went home and had this method tried, and we have now adopted this principle, because, when

the tubes are part beaded like this, after the engine has been in service for seven or eight weeks, it is no trouble to bead them right down to the plate, after the tubes and tube-plate have settled down to their work. We have found a considerable advantage from this, and I might say that we have had less leakage from steel tubes since adopting Mr. Walters' method than when we beaded them down to the plate at the outset.

Mr. Walters—I do not understand the beading of tubes on the back side of the tube-plate.

Mr. Bennett—It is really ridging the tube outwards, and it is done with a racking tool.

Mr. Walters—I understood that you recessed the tube itself down inside the water space.

Mr. Bennett—Yes; that is done.

Mr. Walters—Are your superheater tubes parallel?

Mr. Bennett—No, they are not parallel; they are reduced for from 6-in. to 10-in. in length at the firebox end—that is to say, you have a tube $4\frac{1}{4}$ -in. for about that distance, then increased to $4\frac{3}{4}$ -in., except for 3-in. at the steel tube-plate end, which is $4\frac{7}{8}$ -in. diameter.

Mr. Walters—I do not see where it comes in that you require to recess the tube inside the water space, if the tube is properly beaded off, chamfered off, and the shoulder recess brought up to the tube-plate.

Mr. Flocks—In this case there was no shoulder in the waterway.

Mr. Walters—Were they parallel tubes? If they were, of course it is necessary. If they are the ordinary superheater steam tubes—the large ones—I do not see that it is necessary. All these little things mean pounds, shillings, and pence.

Mr. Bennett—These patent racking tools cost about £12, and are not much good. In fact, I defy anyone to take a 4, 5, 7, or 9 gauge tube and put a recess on the tube by means of a small ridge put on the rollers, as in these tools, and that is why I say that I would prefer an "Enak" expander to do this work, for you then have rollers that will do some good.

Mr. Williams, jun., was speaking about marking off firebox stay-holes from a template. Is it worth while? Is

it worth taking the risk? The point is that you have the human element to take into consideration. Supposing the stay holes did not come opposite to one another or lineable, what do you do?

Mr. Williams, jun.—For twenty years past we have experienced no trouble.

Mr. Bennett—Much depends on the chief marker off. In fact, I doubt whether there is a man who could mark off all the stay holes, and find when the firebox was put in its proper position that every stay was to truth. Of course, if I was criticising, I should most certainly want to try the job over before I passed it.

Mr. Williams, jun.—When you mark off the firebox in the casing, how do you guarantee that you get the hole marked off on the firebox perfectly true in position, as all stays are not square with the casing?

Mr. Bennett—We use a square wooden block with a hole drilled in it to take a long centre punch, then again they are lined off on a certain pitched centre with a template on the outside of the casing wrapper, and you have then got them in their relative position on the firebox; after that, we line our holes off with a chalk line from the pops we have made, and correct them if necessary by means of a firebox strip giving the proper angle of the stays on any bends; and, taking the two methods, I say that you have less chance of making a mistake my way than when you put it down for the marker off to mark off, and get the firebox true in the casing for adjusting roof links and everything else.

Mr. Flocks—Would you use the block for outside radius? How do you use your block then?

Mr. Bennett—You would not require to use the block then. You would take the top stays on the flat and the bottom stays on the flat and centre pop these through the block and pitch in the remainder from the projection template. You have then a known factor.

Mr. Flocks—I understand you to say you use a block. If you use that on all parts, it will lead you astray.

Mr. Bennett—You could not begin to do that.

Mr. Williams, jun.—The human element comes in just as much with the block method. There is as much possibility of error.

Mr. Bennett—Well, there is another point you have to consider. Supposing your driller got out in drilling his casing, you could probably afford to let a stay go a half hole out of pitch, according to the drawing, to save having to scrap the plate; but you would not care to have stays come a half hole out of line, which in this case you certainly would have, if your holes in the copper box had been marked off to a template and drilled. It is the possibility of mistakes happening which we have to try to avoid, and as to the costs, I do not think that has much to do with it. Neither can I see where money is to be saved by any different method than I have adopted, because we can get the firebox foundation ring put on and the box marked off in casing and the centre pops corrected for drilling, and after the box is drilled we clean the rag off the holes and bolt the firebox in casing complete for 24/- the job.

Mr. Williams, sen.—I should just like to show that point, because it is a very interesting one to boilermakers. (Mr. Williams then drew on the blackboard a sketch explaining his idea that, by Mr. Bennett's method, the stays would be at unequal distances on the copper box. He said that, when the box lifted, the chances would be that one stay would have to lengthen and the other jump up, which was one reason why they marked off by template.)

I am only showing this, not that I want to differ from Mr. Bennett with reference to marking off the firebox in or out of casing—the difference is very slight, but we have gone so far as to mark off copper boxes before bending them at all, so that we might have this to contend with as little as possible. By having the stays equally divided, as shown by the sketch, better results were obtained, and the box could lift without distorting one stay or the other.

Mr. Lelean—What Mr. Bennett and I are driving at is this: We use a template fitted to the contour of the firebox, on which is marked off from the drawings the angle each stay should have. We put the long centre punch in line with the template line and punch the inside box. Then we take out the firebox and correct afterwards.

Mr. Bennett—I take it, Mr. Lelean, that my idea and yours are practically alike. You were also speaking about how much the firebox went up when the boiler was in steam, and very interesting your experiment must have been, and I thank you for explaining it so lucidly. Of course, we know the roof of the firebox comes down relatively to the outside. The outside comes down on a round-crown boiler, and the

displacement is taken up in the unstayed portion of the wrapper between the copper stays and the roof stays. We find in the direct-stayed boilers we have more flexibility there. With a long box, taking the measurements from the centre of the crown inside, the crown will appear to have come down as much as $\frac{1}{4}$ -in. when full pressure of steam is on.

Mr. Suffield, the Chairman, then moved a vote of thanks to Mr. Bennett for his highly interesting and instructive paper. This was seconded by Mr. Williams, sen., and carried unanimously, Mr. Bennett suitably replying, and proposing a vote of thanks to Mr. Smith for his work at the lantern during the evening, etc.

FIG. 1.

FIG. 2.

FIG. 4.

FIG. 5.

FIG. 6.

FIG. 7.

FIG. 8.

FIG. 9.

FIG. 10.